Importance of Low Order Riparian Ecosystems and a Rapid, Reference-based Approach for Assessing Condition

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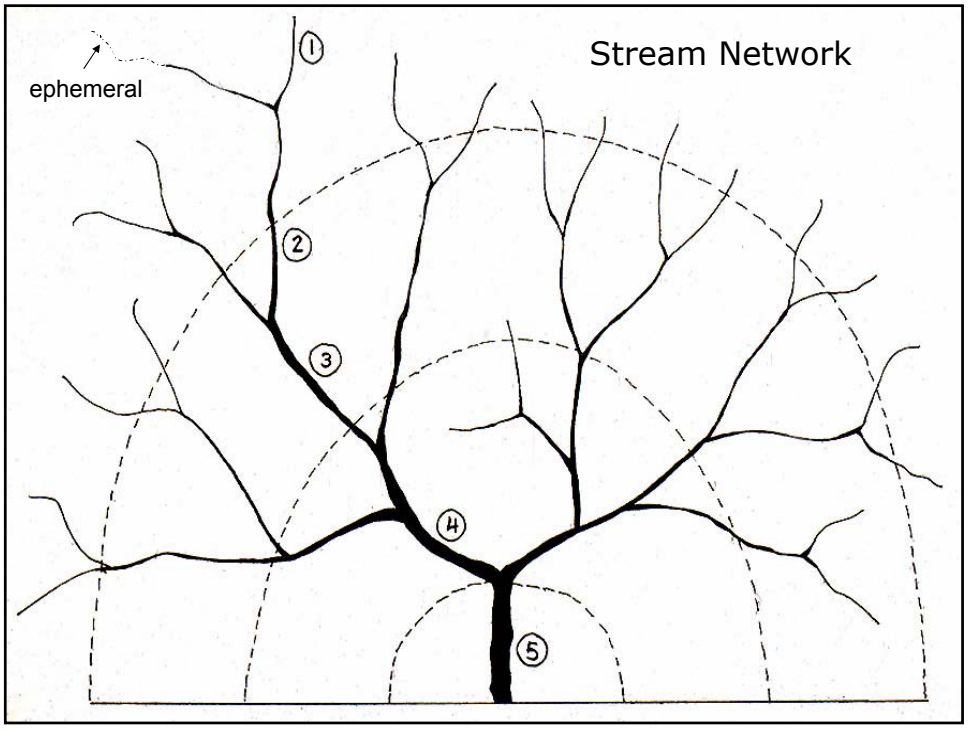
Objectives

1. Provide overview of ecological services provided by riparian ecosystems
2. Outline relationships between functions and resource condition as measured by field metrics
3. Show how ecological condition can be assessed at the reach scale, using examples from North Carolina
4. Show how information on reach condition can be used to evaluate stream network condition

Functions of Riverine Wetland Classes Listed by Four Major Categories

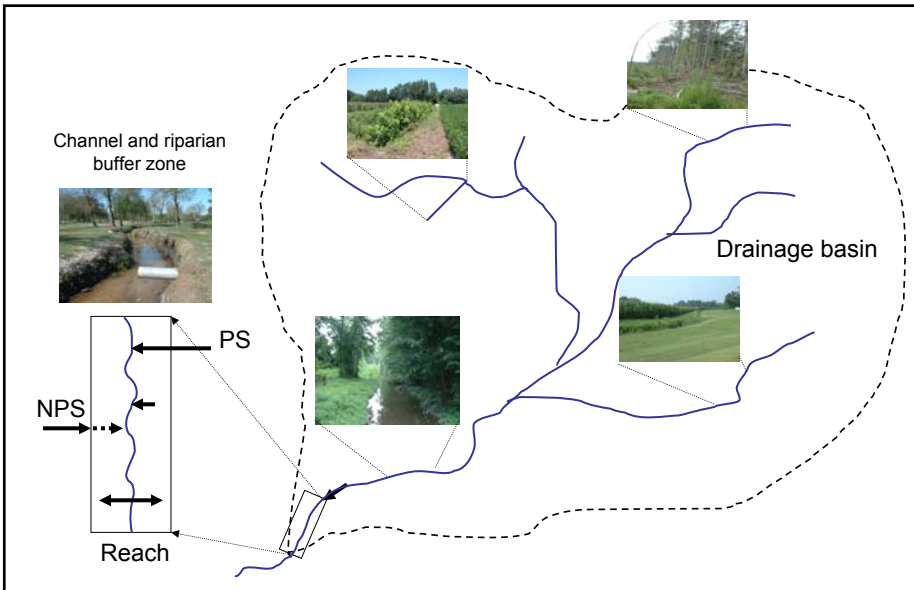
	Values
Hydrologic Dynamic Surface Water Storage Long-Term Surface Water Storage Energy Dissipation Subsurface Storage of Water Moderation of Groundwater Flow or Discharge	Flood attenuation
Biogeochemical Nutrient Cycling Removal of Imported Elements and Compounds Retention of Particulates Organic Carbon Export	Water quality
Plant Habitat Maintain Characteristic Plant Communities Maintain Characteristic Detrital Biomass Animal Habitat Maintain Spatial Structure of Habitat Maintain Interspersion and Connectivity Maintain Distribution and Abundance of Invertebrates Maintain Distribution and Abundance of Vertebrates	Biodiversity, food, fiber



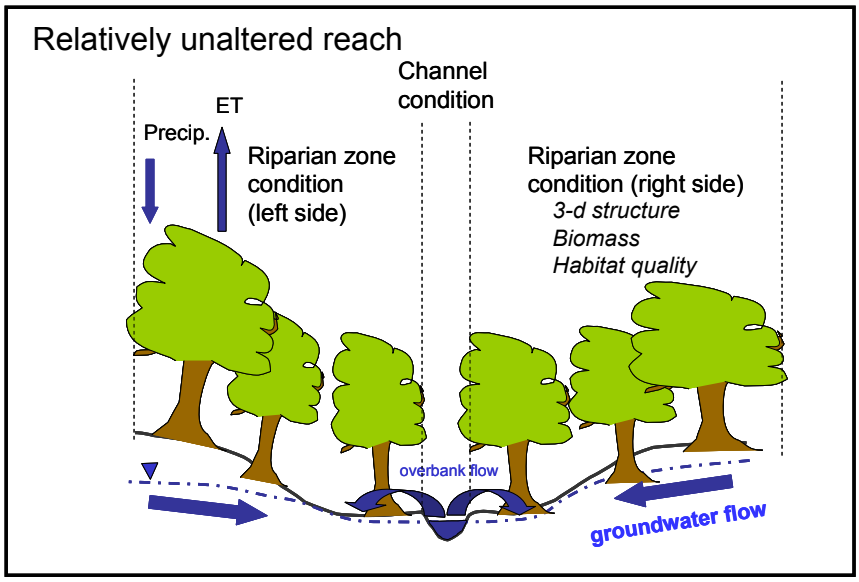
Lengths of streams & drainage basin area, by order, from blue lines on 1:24,000 topographic maps (inner Coast Plain of North Carolina)

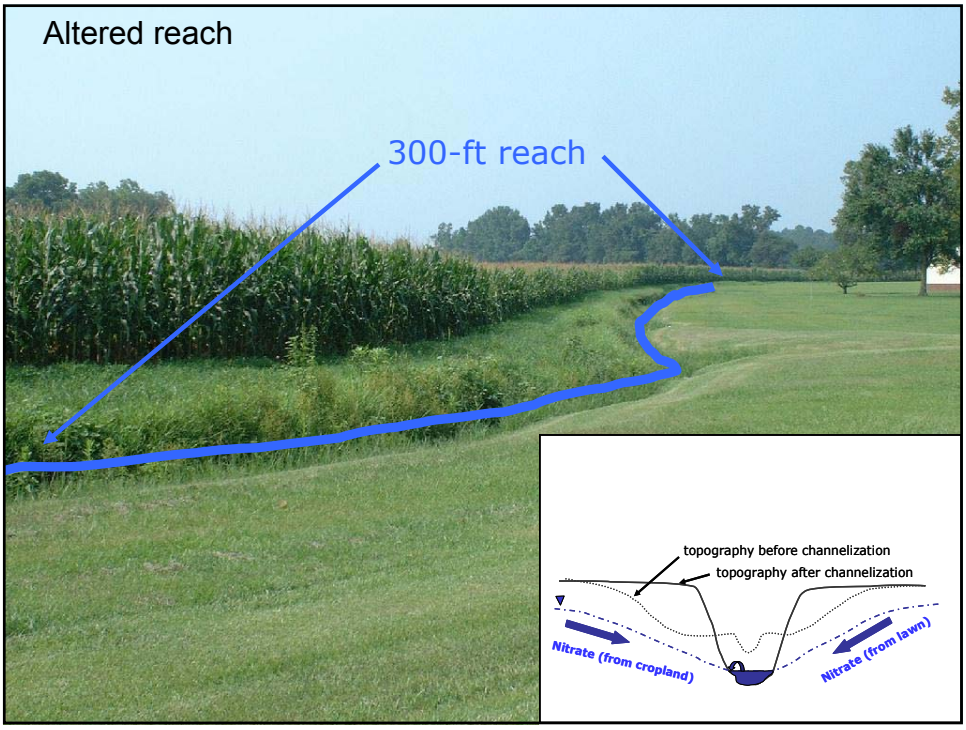
Order[1]	% Total length	Cumulative % length	Drainage basin (ha)
1	62	62	287
2	18	80	796
3	6	86	2,524
4	6	92	10,790
5	2	94	44,354
6+	6	100	?

[1] Does not include most intermittent (seasonal) reaches of streams



Riparian ecosystem = linear resource
- condition of upper reaches affects the condition of lower reaches
- non-point-source pollution interacts with buffer zone along a reach


Relatively unaltered reach
Channel condition
ET
Precip.
Riparian zone condition (left side)
Riparian zone condition (right side)
3-d structure
Biomass
Habitat quality
overbank flow
groundwater flow


Altered reach
300-ft reach
topography before channelization
topography after channelization
Nitrate (from cropland)
Nitrate (from lawn)

Variations in riparian and channel condition

Potential Indicators of Riparian Condition

1. Riparian buffer condition (0-30 m), distance weighted
2. Near-stream riparian condition (0-3 m)
3. Woody structure within stream
4. Hydrologic connectivity between riparian zone and channel
5. Degree of sedimentation
6. Pollution entering stream
7. Pollution entering riparian zone
8. Age/biomass/maturity of riparian zone
9. Habitat quality of riparian zone

Relationship between indicators of condition and ecological functions

INDICATORS	STREAM CHANNEL			RIPARIAN ZONE		
	Hydrology	Biogeo-chemistry	Habitat	Hydrology	Biogeo-chemistry	Habitat
Riparian zone cover (RZC)				X	X	X
Near-stream cover (NSC)		X	X			
Instream woody structure (IWS)	X	X	X			
Sediment regime (SR)		X				
Channel-riparian zone connection (CRZC)	X	X	X	X	X	X
Pollution affecting stream (PAS)	X	X	X			
Factors affecting riparian zone (FARZ)				X	X	X
Habitat quality of riparian zone (HQRZ)						X
Stream bank stability (SBS)		X	X			

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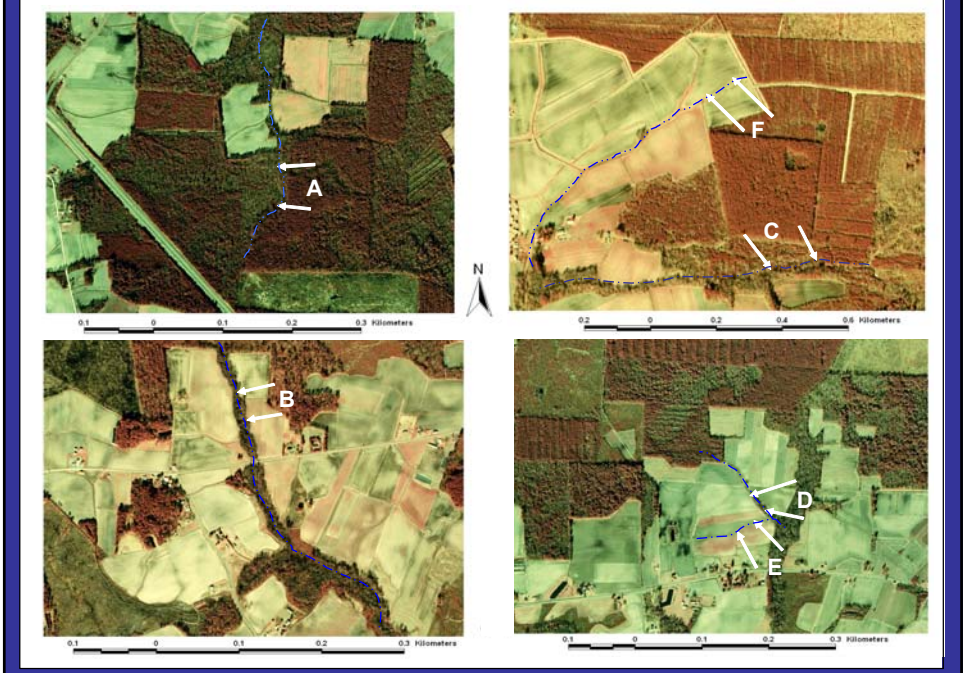
Sediment regime (SR)		X				
Channel-riparian zone connection (CRZC)	X	X	X	X	X	X
Pollution affecting stream (PAS)	X	X	X			
Factors affecting riparian zone (FARZ)				X	X	X
Habitat quality of riparian zone (HQRZ)						X
Stream bank stability (SBS)		X	X			

Experimental units to test relationship between water quality and riparian zone condition

Site	Channel condition	Inner Riparian zone (0-15m)	Outer Riparian zone (>15m)
A	Natural	Forest	Forest
B	Natural	Forest	Partial row crop
C	Natural	Forest	Partial row crop
D	Channelized	Partial forest	Row crop
E	Channelized	Perennial herb	Row crop
F	Channelized	Vegetated ditch	Row crop



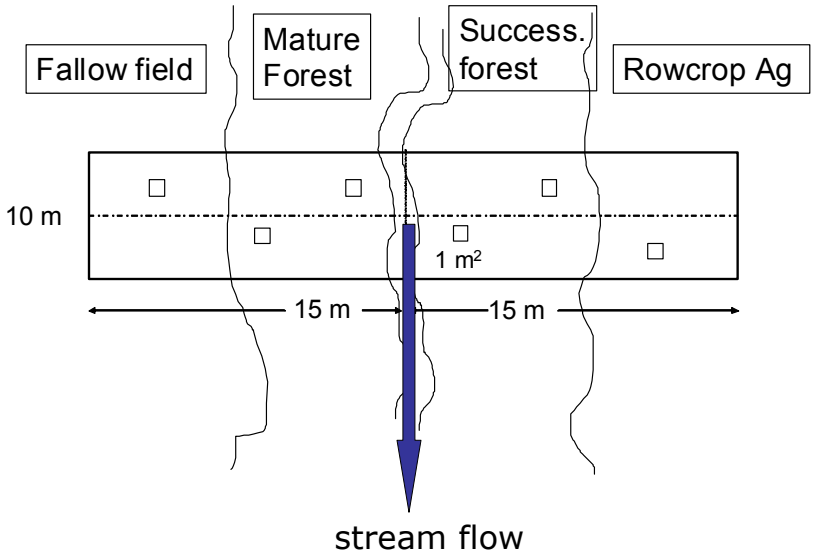

Least Altered (A)

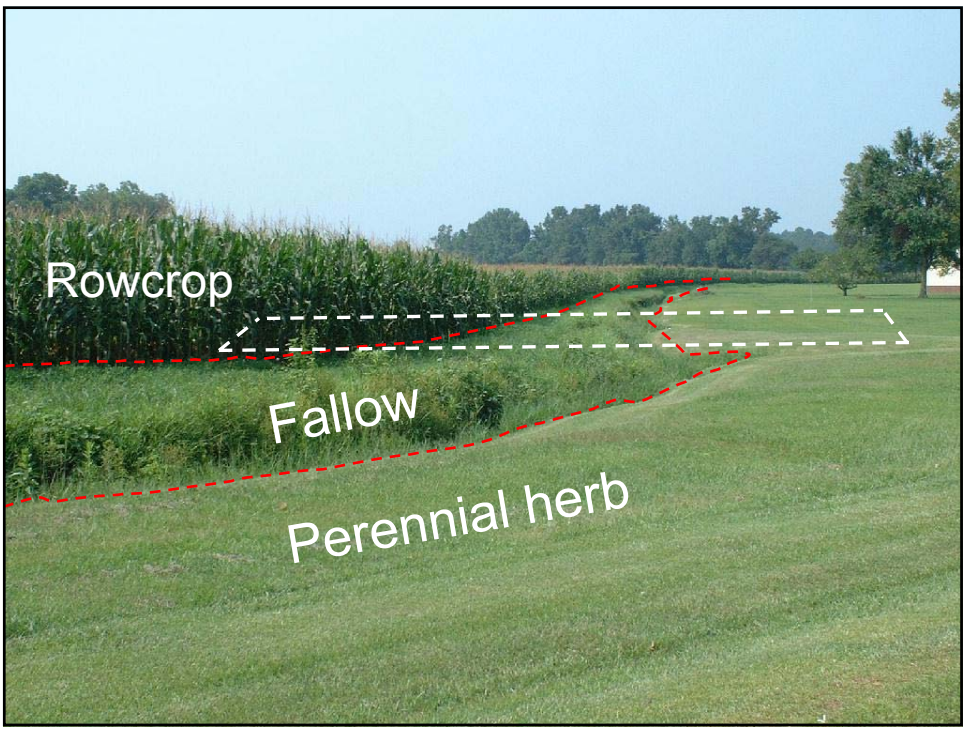

Intact buffer in a agricultural landscape (B)

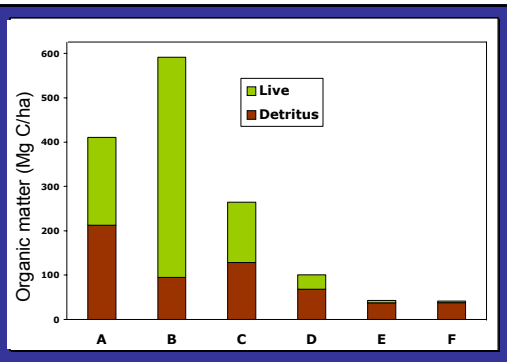

Single-tree buffer (D)


Altered (E)

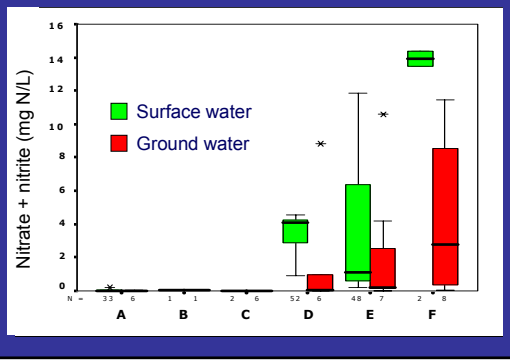
Biomass measurements partitioned by cover types (n=19 reaches)





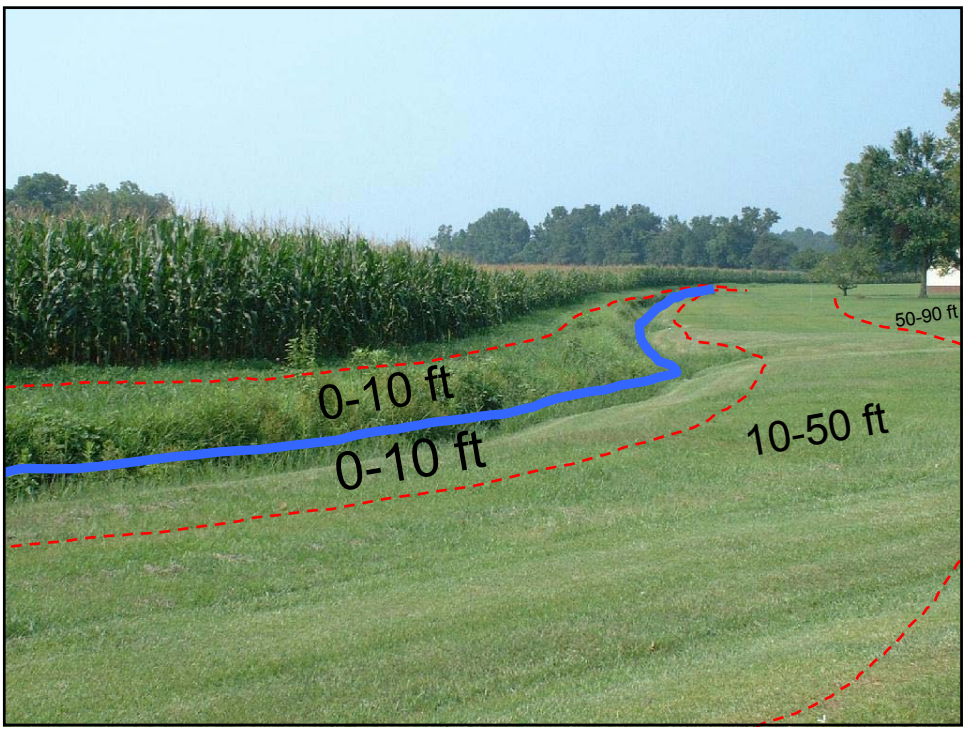


Biomass



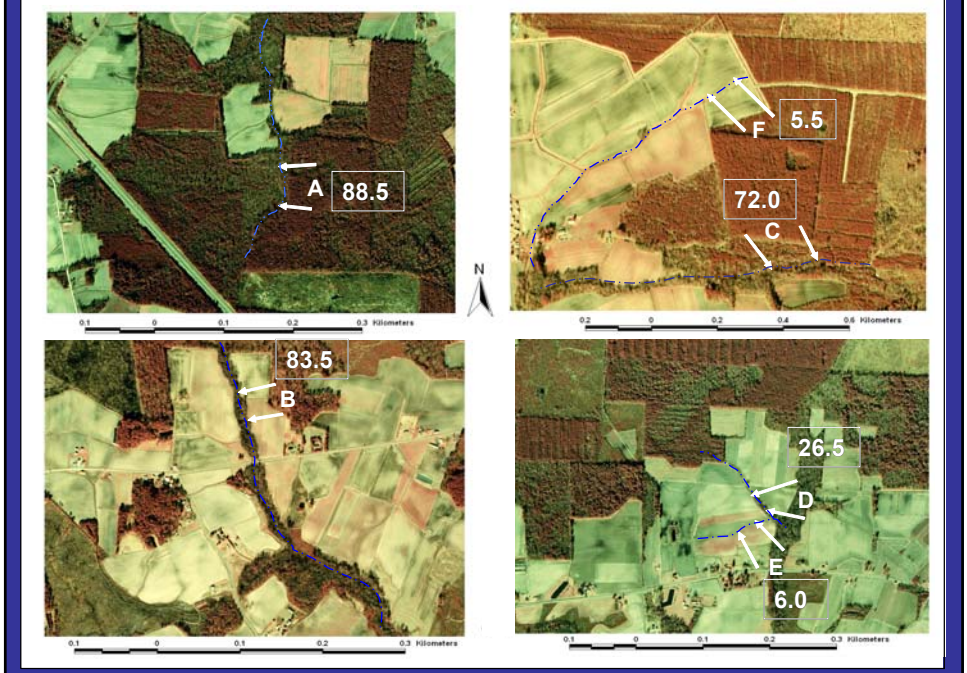
Nitrogen

(Nitrate + nitrite)



RZC index by buffer zone (distance weighted approach: 1/d)

Cover type	Age Midpoint	Biomass (MgC/ha)	Derived Biomass Index	RIGHT SIDE ZONES (distance from stream)		
				0-3 m	3-15 m	15-30 m
Old Forest (>75 y)	85.0	440	1.00	20	25	5
Mature Forest (50-75 y)	62.5	375	0.85	17	21	4
Young Forest (25-50 y)	37.5	275	0.63	13	16	3
Successional Forest (5-25 y)	15.0	160	0.36	7	9	2
Recently Harvested (0-5 y)	2.5	70	0.16	3	4	1
Shrubs/Saplings	NA	63	0.14	3	3	1
Perennial Herb (incl. residential lawns)	NA	38	0.08	2	2	0
Annual Rowcrop	NA	20	0.08	1	1	0
Impervious	NA	0	0.00	0	0	0
			Zone Score (column):	17	16	0
			Total Score (biogeochemical indicator):			**33**



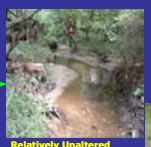
Cover types in reference reaches for which biomass was determined

1. Mature forest (> 50 years old)
2. Young forest (25-50 years old)
3. Successional forest (5-25 years old)
4. Recently clear-cut (0-5 years old)
5. Shrub/saplings
6. Perennial herb (fallow fields, lawns, pasture)
7. Annual rowcrop agriculture
8. Impervious (suburban)

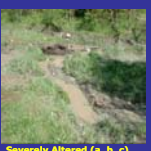
Example of a 4-tiered narrative for an indicator

	Condition Category (degree of alteration)			
Indicator	**Relatively Unaltered**	**Somewhat Altered**	**Altered**	**Severely Altered**
Instream woody structure	Much large down wood (LDW) in channel and along banks. (Recent treefalls from extreme weather events NA.) **(a)** LDW in channel and along banks represents a mix of sizes >4 inch dia^2. Some LDW > 8 inch dia. **(b)** For stream channels that are dry for long periods, tree roots with hypertrophied lenticels are located *in stream bottom.* **(c)** ...etc.	Some LDW in channel and along banks. Some may be partially buried in channel bottom. **(a)** Few or no LDW >8 inch dia. [If large >4 inch dbh trees grow along both banks, score 80, if only along one side, score 70, if streamside trees are <4-inch dbh, score 60.] **(b)** For streams channels that are dry for long periods, .. etc.	Few or no LDW in channel and on banks but potential supply is present. **(a)** LDW represents only one decay class. **(b)** For channelized or deeply incised stream channels, small trees or shrubs grow along channel banks.	No LDW in channel **(a)** Stream is channelized or deeply incised and periodically cleared of debris to maintain drainage. **(b)** No large trees (>4 inch dbh) grow along channel banks. **(c)** Stream is lined with rocks, rip-rap or concrete.
Score =	**100 90**	**80 70 60**	**50 40 30**	**20 10 0**

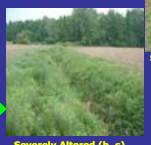
Field data sheets



Relatively Unaltered



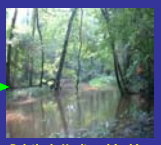
Severely Altered (a, b, c)



Severely Altered (b, c)

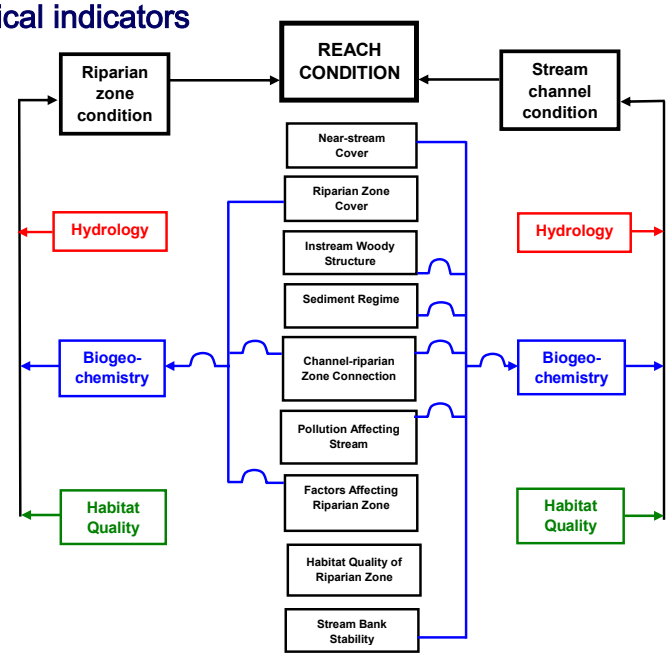
Altered (a)

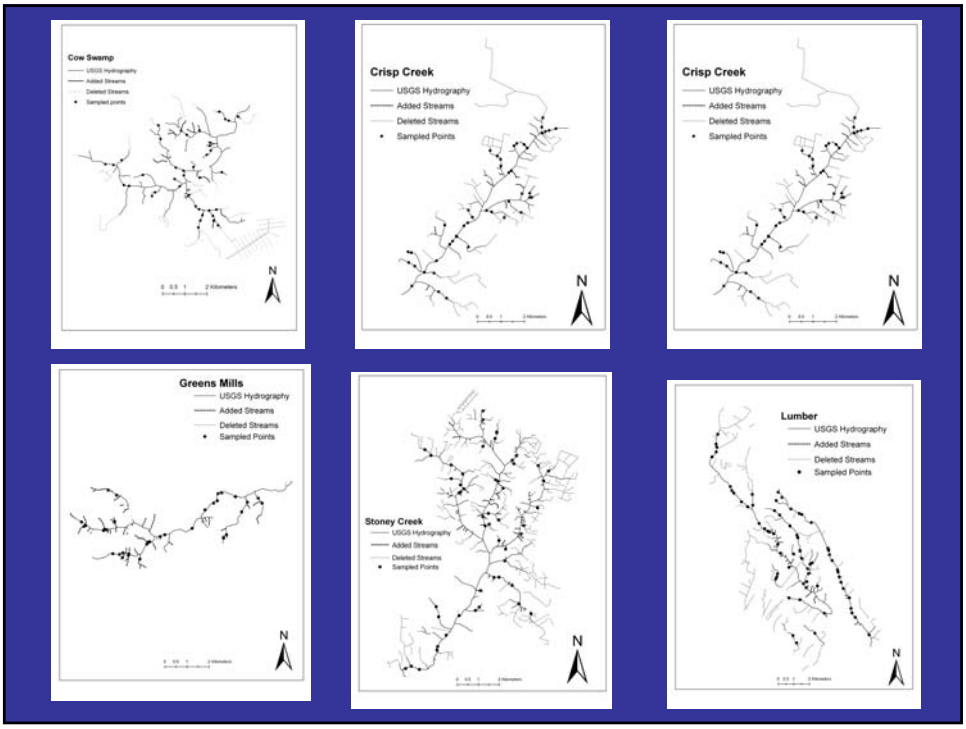
Left – Severely altered (a)



Relatively Unaltered (a, b)

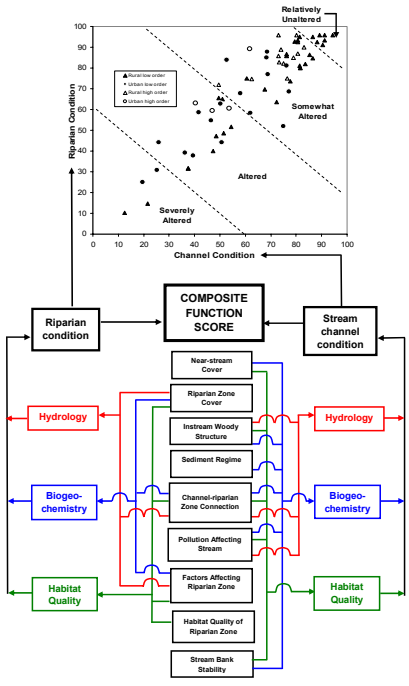
Biogeochemical indicators



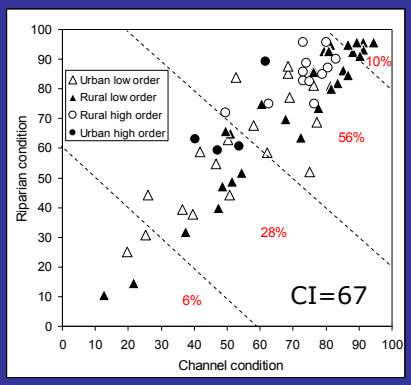


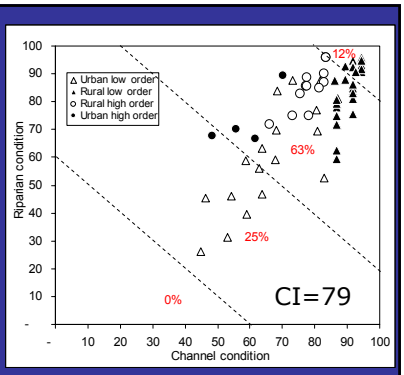
Mean indicator scores can be used to diagnose problems in watersheds or prioritize watersheds for restoration

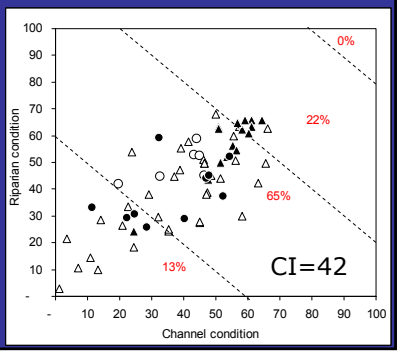
Watershed	Riparian zone cover (RZC)	Near-stream cover (NSC)	Instream woody structure (IWS)	Sediment regime (SR)	Channel-riparian zone connection (CRZC)	Pollution affecting stream (PAS)	Factors affecting riparian zone (FARZ)	Habitat quality of riparian zone (HQRZ)	Stream bank stability (SBS)
Cow	38	41	45	31	25	49	29	34	45
Crisp	31	37	44	32	10	45	17	22	44
Green Mill	71	79	66	33	43	54	38	25	45
Hendricks	64	73	61	57	62	65	59	25	31
Stoney	70	72	66	51	67	59	79	60	57
Lumber	43	47	55	30	37	50	44	32	74



Enhancement/restoration







Increased sub-urbanization

Natural stream channel with mature, forested buffer

Channelized stream without a buffer

Reference-based Approach

- Uses a gradient of conditions as a scale for ranking sites
- Identifies indicators that can be used to characterize condition and diagnose problems
- If a ranking of site condition can be agreed upon, the scaling of indicators of condition can follow
- Indicator condition is converted to numerical scales

*Attributes of useful indicators**

- Ability to measure impairment, relative to reference conditions
- Scientifically accurate
- Repeatable among users
- Can be rapidly measured
- Sensitive to relevant spatial and temporal scales

* Adapted from Brooks, R.P.,D.H. Wardrop, K.W. Thorton, D. Whigham, C. Hershner, M.M. Brinson, and J.S. Shortle, eds. 2006. Integration of ecological and sociological indicators for estuaries and watersheds of the Atlantic Slope. Final report to U.S. EPA STAR Program, Agreement R-82868401, Washington, DC. Prepared by the Atlantic Slope Consortium, University park, PA, USA. *http://www.asc.psu.edu/overview.asp*

Take home message

1. Low order riparian ecosystems intercept most non-point-source pollution on the landscape because they contribute to >90% of stream length
2. Stream channel, riparian zone are interdependent ecologic entities
3. Riparian condition can be evaluated using a reference-based approach measuring structural elements of the ecosystem

Useful References

Rheinhardt, R., M. Brinson, R. Christian, K. Miller, G. Meyer. 2005. Applying Ecological Assessments to Planning Stream Restorations in Coastal Plain North Carolina. Report to the Ecosystem Enhancement Program, North Carolina Department of Environment and Natural Resources, Raleigh, NC, USA. http://www.nceep.net/pages/resources.htm

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Rheinhardt, R., M. McKenney-Easterling, M. Brinson, J. Rubbo, R. Brooks, D. Whigham, D. O'Brien, J. Hite, and B. Armstrong. *In press.* Canopy composition and forest structure as indicators of habitat condition in headwater riparian ecosystems. *Restoration Ecology*.

Rheinhardt, R., M. Brinson, R. Christian, K.H. Miller, G. Meyer. *In press.* A referenced-based framework for evaluating the ecological condition of stream networks in small watersheds. (*Wetlands* as part of a special issue about watershed assessment.)

Rheinhardt, R., M. Brinson, R. Brooks, M. McKenney-Easterling, J. Rubbo, J. Hite, and B. Armstrong. 2007. Development of a referenced-based method for identifying and scoring indicators of condition for coastal plain riparian reaches. *Ecological Indicators* 7:339-361. http://www.nceep.net/pages/resources.htm

Derived from Landscape Development Intensities (LDI) of Brown and Vivas (2005)

Land use by cover type	LEFT SIDE ZONE (distance from stream)						RIGHT SIDE ZONE (distance from stream)					
	0-3 m	%	3-15 m	%	15-30 m	%	0-3 m	%	3-15 m	%	15-30 m	%
Old Forest	20		25		5		20		25		5	
Mature Forest	20		25		5		20		25		5	
Young Forest	19		24		5		19		24		5	
Successional Forest	19		23		5		19		23		5	
Recently Harvested	18		22		5		18		22		5	
Shrubs/Saplings	17		21		4		17		21		4	
Perennial Herb	16	100	2		4		16	100	2		4	
Low intensity pasture	15		20		4		15		20		4	
Annual rowcrop	14		18		3		14		18	100	3	100
Low density residential			15	100	3	100			15		3	
Intensely managed lawns	9		11		2		9		11		2	
Medium density residential			7		1				7		1	
High density residential			7		1				7		1	
Medium density mobile homes			6		1				6		1	
High density mobile homes			5		1				5		1	
High density buildings			0		0				0		0	
Impervious	0		0		0		0		0		0	
Total %		100		100		100		100		100		100
RZC Scores		16.0		15.0		3.0		16.0		18.0		3.0
						34.0						**37.0**